

KANSAS DEPARTMENT OF TRANSPORTATION CONSULTANT AGREEMENT

This Amendment is made and entered into this 27th day of JUNE 1989, by and between the Secretary of Transportation of the State of Kansas, hereinafter referred to as "Secretary", and Woodward-Clyde Consultants, consulting engineers with principal offices in ~~Walnut Creek~~, California, hereinafter referred to as "Consultant."

WITNESSETH:

WHEREAS, this Consultant has technical expertise in Pavement Management pursuant to the Agreement for Engineering Services (attachment "A") dated November 1, 1983, hereinafter referred to as "Contract", and the Amendment and Supplement to Kansas Department of Transportation Consultant Agreement (Attachment "B") dated January 7, 1986, hereinafter referred to as "Amendment One", and,

WHEREAS, it is in the best interest of the Secretary to develop at the earliest feasible date, a methodology to select optimal pavement preservation policies for all road categories simultaneously, subject to budgetary constraints, as an enhancement to the Pavement Management System, and,

WHEREAS, it would be to the best interest of the Secretary that said Consultant continue to provide engineering services necessary for the proposed enhancement to the Pavement Management System as set forth in the Contract and Amendment One, and,

WHEREAS, the Secretary now has the data and resources necessary to allow the Consultant to accomplish the proposed enhancement to the Pavement Management System, and,

WHEREAS, the Consultant has submitted a work plan (attachment "C") dated October 4, 1985, for an optional task 16, as part of the proposal for Amendment One, including a budget and a time schedule, hereinafter referred to as "Proposal", which quantify the proposed enhancement to the Pavement Management System for Kansas, and which is acceptable to the Secretary, and,

WHEREAS, it is in the best interests of the parties to have a second amendment and supplement to the Contract to allow for additional time, supplemental work, and increased fees, costs and expense of the Consultant due to addition of Optional Task 16 from the Proposal.

NOW THEREFORE, upon mutual promises and consideration herein before made, the parties agree to again amend and supplement the Contract and Amendment One attached hereto and incorporated by reference herein, to include the tasks, budget, and time schedule designated and described in the Proposal, also attached hereto and incorporated by reference herein as part of Amendment One, to provide the following:

1. Optional Task 16 as described and outlined on pages 10 and 11 of the Proposal are added to the Contract and are acknowledged by the Secretary as the work necessary to enhance the PMS for Kansas.

2. The budget detailed on page 15 of the Proposal is hereby increased by \$26,972 to \$126,247 to allow for an increase in TRAVEL and a fifteen percent (15%) adjustment for inflation from the date of the proposal.

3. Article I, Section 5, Paragraphs 1 and 3 of the Contract and Provision 4 of Amendment One are hereby voided and replaced in their entirety by the following provisions:

The Secretary agrees:

Upon receipt of proper billing, to pay the Consultant for services as follows:

Compensation for the Project shall be made on the basis of the Consultant's actual cost plus a net fee amount of \$53,890 in conformance with the cost principles established in Vol. 1, Ch. 7, Sec. 2 of the Federal-Aid Highway Program Manual and 41 Code of Federal Regulations (CFR) 1-15.000 et.seq.

The upper limit of compensation for the Project shall be \$692,785, which does not include \$4847.81 paid in June, 1985 for work beyond the scope of the Contract. The upper limit includes \$100,000 for computer resources to be provided by the Consultant. At the option of the Secretary, with notice to the Consultant prior to a notice to proceed, these resources may be provided from another source. Exercise of this option will decrease the contract upper limit by an amount up to \$100,000.

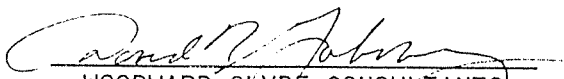
The voucher for final payment for the Project due under the provisions of this Amendment may be submitted after completion and approval by the Secretary of Task 16 in the Proposal.

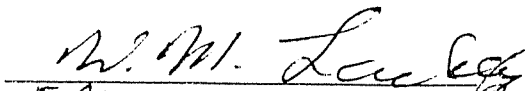
4. Article II, Sections 1 and 2 of the Contract are amended to require a working PMS acceptable to the Secretary at the conclusion of this amended and supplemental agreement, including completion of Task 16 of the Proposal within nine (9) months from this date.

5. The provisions found in Contractual Provisions Attachment (form DA-146a), which is attached hereto and executed by the parties to this agreement, are hereby incorporated in this contract and made a part hereof.

6. The parties agree that all terms of the original Consultant Agreement and attachments of the original agreement, including and not limited to non-discrimination clauses approved by the parties, will have full force and effect and the only modifications in the Contract will be the new completion date, contract amount, and additional tasks set forth.

IN WITNESS WHEREOF, the parties have caused this Amendment and Supplement to Kansas Department of Transportation Consultant Agreement to be signed by their duly authorized officers on the day and year first above written.


WOODWARD-CLYDE CONSULTANTS
David R. Gaboury, P.E.
Vice President and Senior Managing
Principal, Environmental Systems
June 23, 1989


H. B. EDWARDS
Secretary of Transportation
of the State of Kansas
BY: WILLIAM M. LACKEY
State Transportation Engineer

FORM
APPROVED
BY
R. B. 20-89
Legal Dept.
KDOT

CONTRACTUAL PROVISIONS ATTACHMENT

Important: This form contains mandatory contract provisions and must be attached to or incorporated in all copies of any contractual agreement. If it is attached to the vendor/contractor's standard contract form, then that form must be altered to contain the following provision:

"The provisions found in Contractual Provisions Attachment (form DA-146a), which is attached hereto and executed by the parties to this agreement, are hereby incorporated in this contract and made a part hereof."

The undersigned parties agree that the following provisions are hereby incorporated into the contract to which it is attached and made a part thereof, said contract being the ____ day of _____, 19____.

1. TERMS HEREIN CONTROLLING PROVISIONS

It is expressly agreed that the terms of each and every provision in this attachment shall prevail and control over the terms of any other conflicting provision in any other document relating to and a part of the contract in which this attachment is incorporated.

2. AGREEMENT WITH KANSAS LAW

All contractual agreements shall be subject to, governed by, and construed according to the laws of the State of Kansas.

3. TERMINATION DUE TO LACK OF FUNDING APPROPRIATION

If, in the judgment of the Director of Accounts and Reports, State Department of Administration, sufficient funds are not appropriated to continue the function performed in this agreement and for the payment of the charges hereunder, State may terminate this agreement at the end of its current fiscal year. State agrees to give written notice of termination to contractor at least 30 days prior to the end of its current fiscal year, and shall give such notice for a greater period prior to the end of such fiscal year as may be provided in this contract, except that such notice shall not be required prior to 90 days before the end of such fiscal year. Contractor shall have the right, at the end of such fiscal year, to take possession of any equipment provided State under the contract. State will pay to the contractor all regular contractual payments incurred through the end of such fiscal year, plus contractual charges incidental to the return of any such equipment. Upon termination of the agreement by State, title to any such equipment shall revert to contractor at the end of State's current fiscal year. The termination of the contract pursuant to this paragraph shall not cause any penalty to be charged to the agency or the contractor.

4. DISCLAIMER OF LIABILITY

Neither the State of Kansas nor any agency thereof shall hold harmless or indemnify any contractor beyond that liability incurred under the Kansas Tort Claims Act (K.S.A. 75-6101 *et seq.*)

5. ANTI-DISCRIMINATION CLAUSE

The contractor agrees: (a) to comply with the Kansas Act Against Discrimination (K.S.A. 44-1001 *et seq.*) and the Kansas Age Discrimination in Employment Act (K.S.A. 44-1111 *et seq.*) and to not discriminate against any person who performs work hereunder, because of race, religion, color, sex, physical handicap unrelated to such person's ability to engage in this work, national origin or ancestry, or age; (b) to include in all solicitations or advertisements for employees, the phrase "equal opportunity employer"; (c) to comply with the reporting requirements set out at K.S.A. 44-1031 and K.S.A. 44-1116; (d) to include those provisions in every subcontract or purchase order so that they are binding upon such subcontractor or vendor; (e) that a failure to comply with the reporting requirements of (c) above or if the contractor is found guilty of any violation of such act by the Kansas Commission on Civil Rights, shall constitute a breach of the contract and it may be cancelled, terminated or suspended in whole or in part by the Director of Purchases, State Department of Administration.

Parties to this contract understand that subsections (b) through (e) of this paragraph number 5 are not applicable to a contractor who employs fewer than four employees or whose contract with this agency of the Kansas state government total less than \$5,000 during this fiscal year.

6. ACCEPTANCE OF CONTRACT

This contract shall not be considered accepted, approved or otherwise effective until the statutorily required approvals and certifications have been given.

7. ARBITRATION, DAMAGES, WARRANTIES

Notwithstanding any language to the contrary, no interpretation shall be allowed to find the State or any agency thereof has agreed to binding arbitration, or the payment of damages or penalties upon the occurrence of a contingency. Further, the State of Kansas shall not agree to pay attorney fees and late payment charges beyond those available under the Kansas Prompt Payment Act (K.S.A. 75-6103), and no provision will be given effect which attempts to exclude, modify, disclaim or otherwise attempt to limit implied warranties of merchantability and fitness for a particular purpose.

8. REPRESENTATIVE'S AUTHORITY TO CONTRACT

By signing this document, the representative of the contractor thereby represents that such person is duly authorized by the contractor to execute this document on behalf of the contractor and that the contractor agrees to be bound by the provisions thereof.

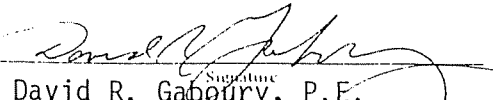
9. RESPONSIBILITY FOR TAXES

The State of Kansas shall not be responsible for, nor indemnify a contractor for, any federal, state or local taxes which may be imposed or levied upon the subject matter of this contract.

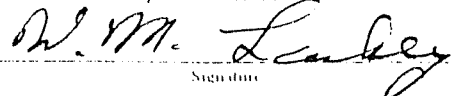
10. INSURANCE

The State of Kansas shall not be required to purchase, any insurance against loss or damage to any personal property to which this contract relates, nor shall this contract require the state to establish a "self-insurance" fund to protect against any such loss or damage. Subject to the provisions of the Kansas Tort Claims Act (K.S.A. 75-6101 *et seq.*), the vendor or lessor shall bear the risk of any loss or damage to any personal property in which vendor or lessor holds title.

Vendor/Contractor:

4/27/89 
Date Signature
David R. Gaboury, P.E.
Vice President and Senior Managing
Principal, Environmental Systems
Title

Agency Head/Authorized Representative:

6-27-89 
Date Signature
State Transportation Engineer
Title

RESOLUTION

BE IT RESOLVED on this 6th day of September 1989, that I, CHARLES L. MILLER, as Director of the Arizona Department of Transportation, have determined that it is in the best interests of the State of Arizona that the Department of Transportation, acting by and through the Highways Division, to enter into an agreement with the State of Kansas and the State of Alaska for the purpose of defining responsibilities for the joint participation in a project to enhance the Pavement Management System.

Therefore, authorization is hereby granted to draft said agreement which, upon completion, shall be submitted for approval and execution by the Deputy State Engineer.



CHARLES L. MILLER, Director
Arizona Department of
Transportation

Development of a Total Pavement Management System - Phase III

AGREEMENT FOR ENGINEERING SERVICES

This Agreement entered into this 1st day of November, 1983; by and between the Secretary of Transportation for the State of Kansas, hereinafter called the "Secretary" and Woodward-Clyde Consultants, Consulting Engineers, with principal offices in Walnut Creek, California, hereinafter called "Consultant".

WITNESSETH:

That the Secretary proposes to continue the development and implementation of a "Total Pavement Management System" (PMS).

The subject services are hereinafter called "Project".

That the engineering forces of the Secretary will be unable to handle the work involved within the desired completion date.

That the Secretary is authorized by law to secure engineering services, to make engineering studies and to take such steps as may be necessary to fully participate in the benefits to be secured from funds which may be made available for the improvement of State Highways or city connecting links on the State Highway System.

That the Secretary desires to engage services of the Consultant including, but not necessarily limited to, the following:

OBJECTIVE:

To continue the development and implementation of a Total Pavement Management System as follows:

To implement the Network Optimization System (NOS) computer programs for all road categories;

To develop, test and debug a Project Optimization System (POS).

SCOPE OF WORK:

The following tasks will be undertaken in order to accomplish the objectives of the proposed Project.

TASK 1. Complete the Development of Interim Prediction Models for the NOS

This task will include the analysis of the subjective data, collected on assessment forms during the previous Phase II Agreement from experts within the Secretary's organization, to determine consensus values for all of the necessary final level transition probabilities for road categories numbered 1 through 14 and 16 through 23, as identified in the Phase II Final Report. The following steps will be involved in completing the development of interim prediction models for the NOS:

- a.) The Secretary will be responsible for providing the data from the assessment forms to the Consultant on computer tape within one week from the date of execution of this agreement using the format previously approved by the Consultant.
- b.) The Consultant will analyze the data to determine consensus values for all of the necessary level transition probabilities for the above specified 22 road categories. Prior to the data analysis, an examination of the data will be made by the Consultant to identify and eliminate any inconsistent or disjoint data. After all consensus values have been determined, a computer tape of the level transition probabilities will be submitted to the Secretary. The level transition probabilities for road category 15, determined previously in the Phase II Agreement, will also be included on the tape.
- c.) The Secretary will review the level transition probabilities for consistency and expected trends across the different road categories and actions. Level transition probabilities for road category 15 will also be re-evaluated, and modified as necessary, for compatibility with those of all other road categories. Appropriate revisions, as required, will be made by the Secretary and a revised data tape will be provided to the Consultant for final review and concurrence. Receipt of notification of concurrence from the Consultant by the Secretary will constitute satisfactory completion of this task.

TASK 2. Complete NOS Data Analysis and Run NOS Programs for All Road Categories

NOS programs for road category 15 were tested within the Phase II Agreement using approximate data. This task will involve the further testing of NOS programs for all 23 road categories. The following items will be required:

a.) Cost Data for Alternative Actions

The Secretary will provide cost data for the rehabilitation actions associated with the 23 road categories in the format provided by the Consultant during the Phase II Agreement.

The Consultant will furnish guidance as required to develop the INCOST file particularly in the area of routine maintenance costs.

b.) Specification of Feasible Actions

The Secretary will specify feasible actions for each distress state within the 23 road categories using the same format specified for road category 15 during the Phase II Agreement.

c.) Specification of Performance Standards

The Consultant will provide specific procedures and master forms for use in establishing performance standards and will demonstrate the procedures to a small task group of upper level Kansas Department of Transportation management. The Secretary will appoint the task group and assemble the group to meet with members of the Consultant's staff during the first month of the Project. The meeting will be held in Topeka, unless another location is agreed to by the Secretary or his

representatives and will be held in conjunction with the visit required for task 6. The Consultant will analyze the data and provide tentative performance standards for review by the Secretary's staff.

d.) Run the NOS Programs to Produce an Optimal Solution For All Road Categories

The Secretary will furnish the data listed in Tasks 2a, 2b, and 2c as well as the current network condition to the Consultant in the format specified for road category 15 in the Phase II Agreement. The Consultant will assemble all input data files needed to run the NOS programs and transmit them to the University of Kansas for analysis.

Computer costs incurred on the Consultant's computer to assemble these files will be included in the consideration for this Project. Optimal solutions for the 23 road categories will be obtained by the University of Kansas. Computer costs incurred at the University of Kansas will be paid directly by the Secretary. No computer charges to be paid by the Secretary will be incurred at the University of Kansas without authorization by the Secretary or his designee.

Computer runs for all 23 road categories must be made on the IBM-3031 computer at the University of Kansas using MPS-III Software tested during the Phase II Agreement. All input and output must be through the same IBM computer. The Consultant will be responsible for transmitting the necessary input data to the University of Kansas for analysis and supervising progress of the analysis. Corrections required to input files or software needed to obtain the optimal solutions will be the responsibility of the Consultant and not the University of Kansas staff. The University of Kansas will furnish a summary report to the Consultant and the Secretary for each computer run made. The summary report will be produced using the report writer.

The Consultant and Secretary will mutually choose two or more appropriate road categories for analysis of two problem sizes i.e. 216 versus 432 condition states. The Consultant will analyze the results of 2 or 3 steady-state runs and 2 multi-period runs for each problem size and road category. After analysis, the Consultant will make recommendations as to the appropriate problem size to the Secretary prior to proceeding with the runs for the remaining road categories. When the Secretary and Consultant mutually agree on the appropriate problem size, the Consultant and the University of Kansas will be notified by the Secretary to proceed with the runs on the remaining road categories.

This task will be completed when the Secretary receives the following for each road category at the specified problem size (216 or 432 condition states):

- i) a minimum of two steady-state runs.
- ii) two multi-period runs.

TASK 3. Evaluation of NOS Test Program Results

The purpose of this task will be to evaluate the optimal solutions produced by the NOS in Task 2. The assessments will include, but not necessarily be limited to, the following considerations:

- a.) Are the actions recommended for the various condition states reasonable within each road category?
- b.) Are the optimal actions for the same or similar condition states reasonable across different road categories?
- c.) Is the effect on budget levels caused by varying performance standards according to expectations?
- d.) Are the proportions of roads recommended for do nothing, routine maintenance and rehabilitation actions realistic and reasonable?

The primary responsibility for reviewing the test program results for consistency and reasonableness will be assigned to the Consultant. If unreasonable or unexpected results are identified, the Consultant will advise the Secretary of the specific problems or areas of concern. The Consultant will examine the problems defined to identify the causes and prepare and submit to the Secretary recommendations for corrective actions. Potential sources of unreasonable results include: overly optimistic or pessimistic transition probabilities; inflexible specification of feasible actions; incorrect cost estimates; and unreasonable performance standards.

The task will be considered complete with the acceptance by the Secretary of recommendations for corrective actions to eliminate the causes of unacceptable results. Corrective actions will be accomplished in Task 4. If after review test program results are entirely satisfactory to the Secretary, no further work will be required in this task and it will be deemed complete by acceptance of the test program results.

TASK 4. Revision of the NOS Input Files, As Necessary

Appropriate revisions or modifications to the NOS input files to correct problems or deficiencies identified in Task 3 will be accomplished within this task.

The Consultant will be responsible for revising or modifying the NOS input files in accordance with the recommendations agreed upon in Task 3. Additional test runs of the NOS may be required to verify that the program changes yield satisfactory results. All additional test runs will be made at the University of Kansas and will be paid for directly by the Secretary. No computer charges to be paid by the Secretary will be incurred at the University of Kansas without advance authorization by the Secretary or his designee. As in Task 2, the Consultant will be responsible for coordinating the preparation and transmittal of input data to the University of Kansas.

This task will be complete when satisfactory results and related documentation are accepted by the Secretary. Satisfactory results will consist of optimal solutions from new computer runs (steady-state and/or multi-period) for the road categories deemed to need revision in Task 3 and/or detailed recommendations for

modifications to input data which can be made in the future by the Secretary's staff in the event that data processing funds are depleted prior to completion of the desired revisions.

TASK 5. Develop Software to Prepare a Listing of Road Segments and Recommended Actions

The output from the NOS programs is an optimal rehabilitation policy which will consist of a recommended action and its associated cost for each of the various condition states within each road category. In order to correlate the actions recommended by the NOS for year one to the specific road sections within each of the respective condition states, additional software must be developed. Additional software is also necessary to help identify the probable condition and probable action for year two and beyond for all segments in the data base. This software will require use of the transition probability matrices from NOS input file TRMX. This task will include the development and testing of this necessary software.

The Secretary's staff will have the primary responsibility for developing and testing the required software. The Consultant will provide advice and technical assistance as necessary.

TASK 6. Finalize the POS Framework

A concept and basic framework for the Project Optimization System (POS) component of the Pavement Management System was developed in the Phase II Agreement. This task will be concerned with the finalization of the framework for the POS.

The Consultant will meet in Topeka with members of the Secretary's staff to discuss (i) the type of prediction models to be developed for the POS (empirical, mechanistic, or a combination of the two, with subjective and/or objective data); (ii) the process of assessing preference functions; and (iii) mechanistic procedures for new design which are compatible with available data. Factors to be considered during the discussions will include:

- (a) How much, and what types of, data are available for the development of performance prediction models?
- (b) Should multiple attributes be used in evaluating alternative rehabilitation strategies for a given project? If yes, what should these factors be and what group of individuals should assess the preferences with respect to the relative importance of the attributes?
- (c) Is the necessary data available for the various mechanistic procedures?

Following these discussions, the Consultant will submit a written report to summarize the decisions made and the potential impact of these decisions on allocated resources for the Project.

Acceptance of the written report by the Secretary will be considered as completion of this task.

TASK 7. Develop POS Prediction Models

Models will be developed within this task to predict the performance of existing pavements under different rehabilitation actions and the performance of new pavements to be built under alternative initial designs. Uncertainties in predicting future performance will be explicitly incorporated in these models. Therefore, the models will predict not only expected performance, but also probabilities of getting performance different from that expected.

The prediction models for existing pavements will be developed on the basis of as built data, performance history of selected test locations and parameters obtained from laboratory testing of samples obtained from selected test sites. Mechanistic procedures will be used as appropriate. A larger number of influence variables will be included initially in the models. Using techniques such as stepwise analysis, a smaller set of influence variables which best reflect the variations in pavement performance will be selected.

For new pavements, the available data will include the design parameters (e.g. material properties, traffic, layer thicknesses, etc.) and previous performance histories. An appropriate combination of mechanistic and empirical procedures will be selected to be compatible with available design data and the procedures developed for existing pavements.

State-of-the-knowledge mechanistic-empirical models will be used for the development of POS pavement design procedures. If such models do not exist for specific distress types, empirical models will be developed for the design procedures.

Four years of performance data for nearly 50% of the cells in the POS experiment (identified in correspondence dated August 4, 1983) is available. One year of performance data is available for the remaining sites. Laboratory test data is not currently available for any of the selected POS experiment test sites.

The Consultant will be responsible for development of the POS prediction models for rehabilitated Portland Cement concrete pavements, rehabilitated composite pavements, rehabilitated full design bituminous pavements, and new rigid and flexible pavements. The models will be developed using available information and that which can reasonably be obtained by the Secretary's staff during the project. Sufficient data is not expected to be available to develop the interim prediction models for rehabilitated partial design bituminous pavements.

This task will be complete when prediction models have been developed for the pavements types identified above and are accepted by the Secretary. Documentation will include detailed instructions on how to make the necessary modifications to the models as more experimental and actual data becomes available over time.

TASK 8. Establish Preference Functions

Multiple attributes will be required for the evaluation of feasible rehabilitation strategies. The relative importance of the attributes will be established in this task. Formal procedures for assessing multi-attribute

preference functions will be used. A panel with members from the Secretary's staff will be selected to make the necessary assessments of acceptable tradeoffs between competing attributes.

A group meeting, to be coordinated and conducted by the Consultant, will be held in Topeka to explain to the panel members the purpose of the assessments and the procedure that will be followed. The Consultant will design and prepare assessment forms to be completed by the panel members. The assessment forms will be designed so that answers can be keypunched directly from the forms onto tape. To determine if a reasonable group consensus can be identified from the responses, a statistical analysis will be performed. If the responses are extremely divergent, a second iteration of the appropriate assessment forms will be performed as necessary.

Based upon the group consensus identified for the various assessments, a multi-attribute assessment function will be calibrated by the Consultant. The procedure for calibration and the major implications of the preference function will also be documented in a summary report to be prepared by the Consultant.

Completion of this task will be contingent upon a review and acceptance of the above mentioned report by the Secretary.

TASK 9. Develop Computer Program for Implementation Of The Project Optimization System

This task will involve the development of the overall computer program for the implementation of the POS, and will include the following components or subroutines:

a.) Form cost and performance constraints

For a rehabilitation project, these constraints will be formed based on NOS results. The upperbound on the project cost will be the sum of the cost of the recommended NOS action for each segment in the project. The performance constraints will be: (i) the minimum probability that a random part of the project is in acceptable condition at each year during the five-year planning period and (ii) the maximum probability that a random part of the project is in unacceptable condition at each year.

For new construction, the cost constraint probably will come from the construction priority/optimization system. Initially, this constraint may have to be set based on past experience and judgment. The performance constraints will have to be set by policy decisions; for example, the expected time to the first major rehabilitation action should be more than ten years.

b.) Find feasible sets of actions

The cost of a feasible action set for a rehabilitation project should be less than or equal to the upperbound on project cost calculated above. In addition, the performance under the action set, as determined from the POS prediction model, should be equal to or better than the performance constraints formed from the NOS model.

For new construction, the cost of each alternative design will be determined from the design specifications and previous cost records. The performance of a new pavement after it is built will be estimated from the appropriate mechanistic model selected in Task 7.

- c.) For each feasible action set, calculate the total expected value

The probability distribution of each attribute will be determined for the action set using the prediction models. The total expected value of the action set will then be calculated from the calibrated preference function.

- d.) Rank feasible action sets and conduct sensitivity analyses

The feasible action sets will be ranked in a decreasing order of total expected value. The sensitivity of the ranking will be examined with regard to factors such as: differences of opinions on acceptable tradeoffs between competing attributes and policy requirements for new construction.

The Consultant will be responsible for developing the computer program and all associated computer costs. The program will be designed for compatibility with one of two alternative computer systems: the PLEXUS P/40 at the KDOT Materials-Research Center or the IBM mainframe operated by the State of Kansas Division of Information Systems and Computing (DISC). The preferred alternative will be the PLEXUS P/40.

This task will be considered complete upon notification from the Consultant that the program is ready for installation and testing on the computer facility designated by the Secretary.

TASK 10. Test and Revise POS Program

This task will involve installation, testing, and revision, if necessary, of the POS program developed in Task 9.

The Consultant will provide any advice and/or technical assistance that may be necessary to accomplish the installation and testing of the program on the Secretary's computer facility.

Input data for testing the program will be furnished by the Secretary. A minimum of ten test projects (five rehabilitation and five new construction projects) will be selected.

The results of the POS test runs will be evaluated by the Secretary's staff with respect to anticipated trends and expectations. Any concerns or problems revealed by the examination of the test results will be submitted to the Consultant for review.

The Consultant will analyze the test results to identify the cause of the problem(s) and prepare recommendations for appropriate corrective action. With the concurrence of the Secretary, the Consultant will execute the necessary program revisions. At the discretion of the Secretary, additional test runs may be made to ensure that the revised results are reasonable and satisfactory.

Acknowledgement by the Secretary that the POS program has been successfully implemented and satisfactory results have been obtained will constitute completion of this task.

TASK 11. Prepare a Final Report

This task will consist of the preparation of a final report by the Consultant to document the development of the NOS and POS associated with the tasks defined in this Phase III Agreement. A users manual will also be prepared to describe the input-output characteristics of the POS computer program. Six bound copies of the final report and users manual and an unbound photo-reproducible copy of each will be furnished to the Secretary. Receipt of a final report which accurately and completely documents the development of POS and the refinements to NOS will complete the requirements for this task.

NOW THEREFORE, in consideration of the premises and covenants herein contained, the parties thereto agree as follows:

ARTICLE I

The Secretary agrees:

1. To employ the Consultant to perform the services described herein for the fee stipulated in Article I, Section 5, and in general accordance with the Consultant's proposal which is attached hereto and incorporated herein as Special Attachment No. 3.
2. To designate an employee or employees which will act as principal contact(s) with the Consultant.
3. To notify the Consultant in writing when work on the Project may proceed.
4. To perform the work outlined within the designated tasks as the responsibility of the Secretary in such a manner and within such time frames that the overall project schedule will not be significantly delayed.
5. Upon receipt of proper billing, to pay the Consultant for services as follows:

Compensation for the Project shall be made on the basis of the Consultant's actual cost plus a net fee amount of \$18,722 in conformance with the cost principles established in Vol. 1, Ch. 7, Sec. 2 of the Federal-Aid Highway Program Manual and 41 Code of Federal Regulations (CFR) 1-15.000 et seq. The upper limit of compensation for the Project shall be \$205,934.

During the progress of work covered by this Agreement, partial payments may be made to the Consultant within thirty (30) days of receipt of proper billing, but at intervals of not less than one calendar month. Progress billing shall be supported by a progress schedule acceptable to the Secretary. Accumulated partial payments shall not exceed Ninety-Five Percent (95%) of the total fees earned, prior to approval and acceptance of the completed Project by the Secretary. Partial payments due shall be defined as the accumulated total fees due less the total of previous payments times Ninety-Five Percent (95%).

The voucher for final payment for the Project due under the provisions of this Agreement may be submitted after completion of the Project and acceptance and approval of certain "deliverables" by the Secretary as described in Article II, Section 3 of this Agreement.

ARTICLE II

The Consultant agrees:

1. To produce a working Pavement Management System within five contract phases. During this development period, implementable (interim) packages will be produced.

2. That all tasks will be completed within twelve months from the date this agreement is signed. Tasks will be scheduled as shown in Figure 2 of Special Attachment No. 3.

3. That certain "deliverables" will be furnished to the Secretary. "Deliverables" will include, but not be limited to, a data tape of level transition probabilities, NOS performance standards, a minimum of two steady state and two multiperiod NOS computer runs giving optimal solutions for each road category, revised NOS computer runs with related documentation of input modifications, if necessary, a report stating the final POS framework, POS prediction models, POS multi-attribute preference functions and related summary report, POS computer programs, and a final report.

4. To fully and faithfully perform the work herein described as within the scope of work.

5. To accept compensation for work herein described and that such compensation shall be complete and sufficient payment for all work performed, equipment and material used, and services rendered in connection with such work, and that all such work shall be performed in accordance with approved practices and the rules and regulations of the Secretary. Payment vouchers submitted for work completed under the requirements of this Agreement shall be in the format illustrated on Exhibit "A", which is attached hereto and incorporated herein by reference.

6. To comply with all Federal, State and local laws, ordinances, and regulations applicable to the work, including Title VI and Title VII of the Civil Rights Act of 1964, Executive Order 11246, and non-discrimination clauses which are attached hereto and incorporated herein as "Special Attachment No. 1".

7. To warrant that he or she has not employed or retained any company or person, other than a bona fide employee working solely for the Consultant, to solicit or secure this Agreement, and that the Consultant has not paid or agreed to pay any company or person, other than a bona fide employee working solely for the Consultant, any fee, commission, percentage, brokerage fee, gift, or any other consideration which is contingent upon or resulting from the award or making of this Agreement. For breach or violation of this warranty, the Secretary shall have the right to annul this Agreement without liability, or, at the Secretary's discretion, to deduct from the Agreement price or consideration, or otherwise recover, the full amount of such fee, commission, percentage brokerage fee, gift, or contingent fee. (See Special Attachment No. 2, which is attached hereto and incorporated herein by reference.)

8. To save the Secretary and his or her authorized representatives harmless from any and all costs, liabilities, expenses, suits, judgments, damages to persons or property or claims of any nature whatsoever arising out of or in connection with the negligent performance by the Consultant, his or her agents, employees or subcontractors under the provisions of this Agreement. In this regard it is further understood and agreed that the Consultant shall obtain such reasonable insurance coverage as may be required by the Secretary.

9. That records and books of the Consultant pertaining to work covered by this Agreement shall be available to representatives of the Secretary for audit for a period of three years after date of final payment under this Agreement.

10. To prepare an estimated schedule for performance of component tasks (may be bar chart or other acceptable method) and report actual progress at monthly intervals.

11. To not, without written permission from the Secretary, engage the Services of any person or persons in the employment of the Secretary for any work required by the terms of this Agreement.

12. To accept full responsibility for payment of unemployment insurance, workmen's compensation, and social security as well as all income tax deductions and any other taxes or payroll deductions required by law for his employees engaged in the work authorized by this Agreement.

13. That the Secretary may require the Consultant and sub-contractors to be available for audit at the Secretary's discretion. Accounting methods, cost documentation, and books of said parties will be maintained in accordance with generally accepted accounting principles and will conform to the appropriate provisions of 41 Code of Federal Regulations (CFR) 1-15.000 et seq.

14. To accept full responsibility for the completeness and accuracy of all Tasks to be performed under this Agreement.

ARTICLE III

The parties hereto mutually agree:

1. That the services to be performed by the Consultant under the terms of this Agreement are personal and cannot be assigned, sublet, or transferred without the written consent of the Secretary.

2. That the right is reserved to the Secretary to terminate this Agreement at any time, upon written notice, in the event the Secretary determines that the Project is to be abandoned or indefinitely postponed, or because the services of the Consultant are unsatisfactory, or failure by the Consultant to prosecute the work with diligence or to complete the work within the time limits specified in this Agreement; PROVIDED, however, that in any such case, the Consultant shall be paid the reasonable value of the services rendered up to the time of termination on the basis of the payment provisions of this Agreement.

3. Authorization for Extra Work shall be evidenced by the Secretary in writing.

At the discretion of the Secretary, work not specified in this Agreement or which is considered to be beyond the extent of a reasonable exploration of alternates may be classed as Extra Work. Extra Work will usually be of limited extent and may consist of, but is not necessarily limited to the introduction of limited new items of work beyond the expressed scope of the agreement.

At the option of the Secretary, payment for Extra Work may be made on the basis of actual cost for the total work to return the Project to the state of completion obtained prior to written notice of required change, or payment may be made on lump sum or other mutually-agreed basis. No extra work shall be initiated nor shall compensation be made without prior notice from the Secretary requesting such extra work.

4. SUBSTANTIAL CHANGE: If a substantial change in the amount of work to be done by the Consultant is required, an adjustment of fee will be negotiated. The adjustment of the fee may be an increase or a decrease consistent with the nature and extent of change. Substantial changes will usually, but not necessarily, consist of considerable increase or decrease in scope of the project, or duration of services resulting in an increase or decrease in the Consultant's cost of or the time required for performance of this Agreement. No additional work as a result of a Substantial Change in services required shall be performed nor shall additional compensation be paid except on the basis of the provision of a supplemental agreement.

If a substantial change is required in the amount and/or scope of the project, the Consultant will be given a written notice along with a request for an estimate of the total cost for the performance of the change. Thereafter, consideration will be given to the negotiation of an adjustment in the Agreement price based upon the provisions of a supplemental agreement which may be duly entered into by the contracting parties.

5. That when prime compensation for services required is by the actual cost plus a net fee method, overhead rates will be submitted by the Consultant for audit within seventy-five (75) days after completion of the Consultant's fiscal year. The Consultant will assemble work papers for audit at their normal place of business. Overhead rates will be audited on a yearly basis following the first audit as may be required. Overhead rates will be adjusted at the time of the audit review. If the overhead rate increases or decreases, previous payments will be adjusted to insure that the Consultant is reimbursed for actual costs. Future payments will be based on the latest audit.

6. That an extension of time may be granted the Consultant for delays if recognized by the Secretary as unavoidable, provided such extension of time shall be requested by the Consultant in writing, stating the reasons therefor.

7. That all reports and documents pertaining to the Project mentioned herein shall be prepared in accordance with the Secretary's standard practice and shall become the property of the Secretary upon the completion thereof in accordance with the terms of this Agreement, without restrictions as to their further use.

8. That all disputed matters arising under the subject Agreement will be submitted to a Review Committee for resolution. The Review Committee will be comprised of a maximum of two representatives from each of the contracting parties. The Review Committee shall make its own rules of procedure and shall

have authority to examine records kept by the Secretary and the Consultant. In determining the findings, the majority vote of the Review Committee shall govern. The decision of the Review Committee shall be final and binding.

ARTICLE IV

The correlation, interpretation, and intent of the Agreement Documents, including the Agreement, Exhibits and Special Attachments thereto, shall be as follows:

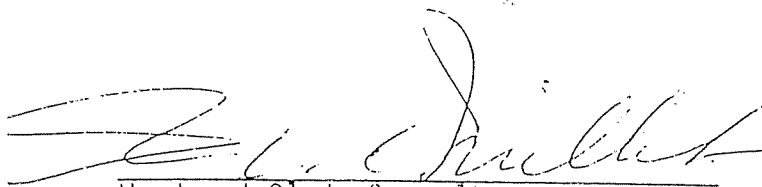
1. The Civil Rights Act of 1964 (Special Attachment No. 1), Certification of Consultant (Special Attachment No. 2), the Consultant's Proposal (Special Attachment No. 3), Attached Exhibits, and the Notice to Proceed, are hereby incorporated by reference into this Agreement, and together with the Agreement and all supplemental agreements hereinafter entered into, shall be defined as the Agreement Documents.

2. The Agreement Documents comprise the entire Agreement between the Secretary and the Consultant. They may be altered only by supplemental agreement.

3. The Agreement Documents are complimentary. What is called for by one is binding as if called for by all. If the Consultant finds a conflict, error, or discrepancy in the Agreement Documents, the Consultant will call it to the Secretary's attention before proceeding with the work affected thereby. In resolving such conflicts, errors, and discrepancies, the documents shall be given precedence in the following order: Special Attachment No. 1; Special Attachment No. 2; Supplemental Agreement; the Agreement excluding any attachments or exhibits; Special Attachment No. 3; Attached Exhibits; and Notice to Proceed.

It is further agreed that this agreement and all contracts entered into under the provisions of this Agreement shall be binding upon the parties hereto and their successors and assigns.

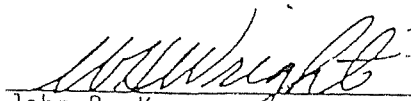
IN WITNESS WHEREOF, the parties have caused this Agreement to be signed by their duly authorized officers on the day and year first above written.



Woodward-Clyde Consultants

Richard A. HILLET

VICE President



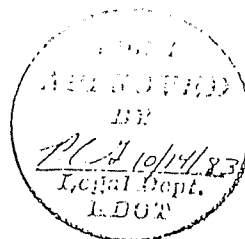
John B. Kemp
Secretary of Transportation
of the State of Kansas

By: W. H. Wright
State Transportation Engineer

ATTEST:

ATTEST:

Approved as to Form:



Note to Consultant: Please submit one original and four copies (two-sided) all with original signatures.

UPDATE ADDRESS

TAX 1 FEIN 4 VIN

TAX 10 NO

TAX 10 NO

AAR USE ONLY

VENDOR INFORMATION

NAME

STREET

CITY, ST, ZIP

TOTAL →

State Agency or Division

KANSAS DEPARTMENT OF TRANSPORTATION

MAIL VOUCHER TO

Mr. G. N. Clark,

Pav't. Management Task Force Leader

KS. Department of Transportation

2300 Van Buren

Topeka, Kansas 66611

Date	Quantity	Unit	Description	Unit Price	Amount																
	EXAMPLE ONLY		<div>Project No. _____</div> <div>County _____</div> <div>Engineering Agreement Date _____</div> <div>Total Compensation not to exceed _____</div> <div>Previously earned _____</div> <div>Previous payments (95%) _____</div> <div>Fixed Fee not to exceed _____</div> <div>Previously earned _____</div> <div>Previous payments (95%) _____</div> <div>Engineering Services from _____ to _____</div> <div> <table> <tr> <th>Name</th> <th>Hours</th> <th>Rate</th> <th>Amount</th> </tr> <tr> <td>J. Doe</td> <td>10</td> <td>10.00</td> <td>100.00</td> </tr> <tr> <td>T. Smith</td> <td>5</td> <td>5.00</td> <td>25.00</td> </tr> <tr> <td></td> <td></td> <td></td> <td>\$125.00</td> </tr> </table> </div>	Name	Hours	Rate	Amount	J. Doe	10	10.00	100.00	T. Smith	5	5.00	25.00				\$125.00		
Name	Hours	Rate	Amount																		
J. Doe	10	10.00	100.00																		
T. Smith	5	5.00	25.00																		
			\$125.00																		

(Continued)

Audited:

Coded:

Approved:

officer in charge

Approved:

Bureau Chief/Dist. Engr.

Total This Voucher \$ _____

Approved:

State Transportation Controller

I do hereby certify that the above bill is just, correct, and remains due and unpaid, and that the amount claimed therein is actually due according to law.

(Sign here) _____

(Firm Name) _____

By _____

Date _____ 19____

I do hereby certify that the within was contracted for the State, under authority of law, and that the amount therein claimed is correct according to such contract and is unpaid.

Secretary

Date _____ 19____

VS 1 QUAL. OPPORTUNITY EMPLOYER

D. O. T. Form No. 424

VS 1 QUAL. OPPORTUNITY EMPLOYER

D. O. T. Form No. 424

UPDATE
ADDRESS

VENDOR INFORMATION

TOTAL →

NAME

STREET

CITY

STATE, ZIP

TAX ID
NO.

STATE AGENCY OR DIVISION

MAIL VOUCHER TO

KANSAS DEPARTMENT OF TRANSPORTATION
Mr. G. N. Clark,
Pay't. Management Task Force Leader
KS. Department of Transportation
2300 Van Buren
Topeka, Kansas 66611

Date	Quantity	Unit	Description	Unit Price	Amount
			Project No. _____ County _____		
			Total from Page 1 = \$125.00		
			Labor	\$125.00	
			Overhead @ 80%	100.00	
			Incidentals	20.00	
			Costs Due Under Agreement	= \$245.00	
			Fixed Fee:		
			Earned to date: 10% x \$3,221.43 =	\$322.14	
			Less prior earnings =	222.14	
			Fixed fee due this statement =	\$100.00	
			Total	\$345.00	
			Less 5%	17.25	
				\$327.75	\$327.75

Audited:

Coded:

Approved:

officer in charge

Bureau Chief/Dist. Engr.

State Transportation Controller

Total This Voucher \$ 327.75

I do hereby certify that the above bill is just, correct, and remains due and unpaid, and that the amount claimed therein is actually due according to law.

(Sign here)

(Firm Name)

By

Date

19

AN EQUAL OPPORTUNITY EMPLOYER

I do hereby certify that the within was contracted for the State, under authority of law, and that the amount therein claimed is correct according to such contract and is unpaid.

Secretary

Date

19

D. O. T. FORM No. 424

KANSAS DEPARTMENT OF TRANSPORTATION

Special Attachment

To Contracts or Agreements Entered Into
By the Secretary of Transportation of the State of Kansas

NOTE: Whenever this Special Attachment conflicts with provisions of the Document to which it is attached, this Special Attachment shall govern.

THE CIVIL RIGHTS ACT OF 1964 AND
REHABILITATION ACT OF 1973

NOTIFICATION

The Secretary of Transportation for the State of Kansas, in accordance with the provisions of Title VI and Title VII of the Civil Rights Act of 1964 (78 Stat. 252), §504 of the Rehabilitation Act of 1973 (87 Stat. 355) and the Regulations of the U.S. Department of Transportation (49 C.F.R., Part 21, 23 and 27), issued pursuant to such Act, hereby notifies all contracting parties that, the contracting parties will affirmatively insure that this contract will be implemented without discrimination on the grounds of race, religion, color, sex, age, physical handicap, or national origin, as more specifically set out in the following eight 'Nondiscrimination Clauses'.

CLARIFICATION

Where the term 'consultant' appears in the following seven 'Nondiscrimination Clauses', the term 'consultant' is understood to include all parties to contracts or agreements with the Secretary of Transportation of the State of Kansas.

Nondiscrimination Clauses

During the performance of this contract, the consultant, or the consultant's assignees and successors in interest (hereinafter referred to as the 'consultant's'), agrees as follows:

- (1) Compliance with Regulations: The consultant will comply with the Regulations of the U.S. Department of Transportation relative to nondiscrimination in federally-assisted programs of the U.S. Department of Transportation (Title 49, Code of Federal Regulations, Parts 21, 23 and 27, hereinafter referred to as the Regulations), which are herein incorporated by reference and made a part of this contract.
- (2) Nondiscrimination: The consultant, with regard to the work performed by the consultant after award and prior to the completion of the contract work, will not discriminate on the grounds of race, religion, color, sex, age, physical handicap, or national origin in the selection and retention of subcontractors, including procurements of materials and leases of equipment. The consultant will not participate either directly or indirectly in the discrimination prohibited by Section 21.5 of the Regulations, including employment practices when the contract covers a program set forth in Appendix B of the Regulations.
- (3) Solicitations for Subcontractors, Including Procurements of Materials and Equipment: In all solicitations either competitive bidding or negotiation made by the consultant for work to be performed under a subcontract including procurements of materials or equipment, each potential subcontractor or supplier shall be notified by the consultant of the consultant's obligation under this contract and the Regulations relative to nondiscrimination on the grounds of race, religion, color, sex, age, physical handicap, or national origin.
- (4) Information and Reports: The consultant will provide all information and reports required by the Regulations, or orders and instructions issued pursuant thereto, and the Secretary of Transportation of the State of Kansas will be permitted access to the consultants books, records, accounts, other sources of information, and facilities as may be determined by the Secretary of Transportation of the State of Kansas to be pertinent to ascertain compliance with such Regulations, orders and instructions. Where any information required of a consultant is in the exclusive possession of another who fails or refuses to furnish this information, the consultant shall so certify to the Secretary of Transportation of the State of Kansas and shall set forth what efforts it has made to obtain the information.
- (5) Employment: The consultant will not discriminate against any employee or applicant for employment because of race, religion, color, sex, age, physical handicap, or national origin.

- (6) Sanctions for Noncompliance: In the event of the consultant's noncompliance with the nondiscrimination provisions of this contract, the Secretary of Transportation of the State of Kansas shall impose such contract sanctions as the Secretary of Transportation of the State of Kansas may determine to be appropriate, including, but limited to,
- (a) withholding of payments to the consultant under the contract until the contractor complies, and/or
 - (b) cancellation, termination or suspension of the contract, in whole or in part.
- (7) Disadvantaged Business Obligation
- (a) Disadvantaged Businesses as defined in the Regulations, shall have the maximum opportunity to participate in the performance of contracts financed in whole or in part with Federal funds under this contract.
 - (b) All necessary and reasonable steps shall be taken in accordance with the Regulations to ensure that Disadvantaged Businesses have the maximum opportunity to compete for and perform contracts. No person(s) shall be discriminated against on the basis of race, religion, color, sex, age, physical handicap or national origin in the award and performance of Federally-assisted contracts.
- (8) Incorporation of Provisions: The consultant will include the provisions of paragraph (1) through (8) in every subcontract, including procurements of materials and leases of equipment, unless exempt by the Regulations, order, or instructions issued pursuant thereto. The consultant will take such action with respect to any subcontract or procurement as the Secretary of Transportation of the State of Kansas may direct as a means of enforcing such provisions including sanctions for noncompliance: Provided, however, that, in the event a consultant becomes involved in, or is threatened with, litigation with a subcontractor or supplier as a result of such direction, the consultant may request the State to enter into such litigation to protect the interests of the State.

CERTIFICATION OF CONSULTANT

I hereby certify that I am the Vice - President and duly authorized representative of the Woodward - Clyde Consultants whose address is One Walnut Creek Center, 1200 N. 1st Ave. and that neither I nor the above firm I here represent has: Walnut Creek, CO 80501

(a) employed or retained for the payment of a commission, percentage, brokerage, contingent fee, or other consideration, any person (other than a bona fide employee working solely for me or the above consultant) to solicit or secure this Agreement,

(b) agreed, as an express or implied condition for obtaining this Agreement, to employ or retain the services of any firm or person in connection with carrying out the Agreement, or

(c) paid, or agreed to pay, to any firm, organization or persons (other than a bona fide employee working solely for me or the above consultant) any fee, contribution, donation, or consideration of any kind for, or in connection with, procuring or carrying out the Agreement;

except as here expressly stated (if any):

I acknowledge that this certificate is to be furnished to the Secretary of Transportation of the State of Kansas in connection with this Agreement and is subject to applicable State and Federal laws, both criminal and civil.

20 Oct 1983
(Date)

[Signature]
CONSULTANT

CERTIFICATION OF THE SECRETARY OF TRANSPORTATION

I hereby certify that I am the Secretary of Transportation of the State of Kansas and that the above Consultant or his representative has not been required, directly or indirectly as an express or implied condition in connection with obtaining or carrying out this Agreement to

(a) employ or retain, or agree to employ or retain, any firm or person, or

(b) pay, or agree to pay, to any firm, person, or organization, any fee, contribution, donation, or consideration of any kind;

except as here expressly stated (if any):

I acknowledge that this certificate is to be furnished to the above referenced firm in connection with this Agreement, and is subject to applicable State and Federal laws, both criminal and civil.

11-1-83
(Date)

[Signature]
John B. Kemp
Secretary of Transportation
of the State of Kansas

CONSULTANT'S PROPOSAL

SCOPE OF WORK FOR PHASE III OF PMS DEVELOPMENT

Objectives

The two primary objectives of the Phase III of the continuing PMS development for KDOT are to:

- o develop, test, and debug a Project Optimization System (POS); and
- o debug and revise the NOS computer programs.

An approach to the development of the POS and the specific tasks that will be undertaken to accomplish these objectives are described below.

POS Framework for Rehabilitation of Existing Pavements

The basic approach is to evaluate alternative action sets for a given project and select the optimum action set based on some selected criteria. It is assumed that the user will identify potential projects and alternative action sets for each project external to the POS. The NOS results should be used as a guideline to form projects. The miles for which a major rehabilitation action is recommended by NOS should be examined to package contiguous miles in similar condition into one project.

A framework for determining the optimal set of actions for a given project is shown in Figure 1. The main steps involved are described below.

1. Find present condition and optimal NOS actions

Using the data base of the most recent pavement condition survey, the present condition state of each mile segment

within the project is identified. The optimal rehabilitation action for each mile segment can then be found from the results of the 5-period NOS run.

2. Form cost and performance constraints

The costs of the optimal actions for different segments in the projects are summed to obtain an upperbound on the total project cost.

To form the performance constraints, the first step is to find the probabilities that each project segment is in acceptable and unacceptable condition states at each of the next five years following the optimal actions. The probabilities are then averaged over all the segments to calculate the probability that any part of the project randomly selected is in acceptable and unacceptable condition states at each of the next five years. If the segments vary in length, a weighted average probability is calculated where the weights would be the length of the segments.

3. Identify alternative sets of rehabilitation actions

Several options can be considered in selecting alternative sets of rehabilitation actions for the given project. One option might be to select a single dominant action for the entire project which would correct most of the deficiencies of the different project segments. Another option might be to combine segments which are in the same or similar condition and adopt one action for these segments. In this option, then, several actions may be selected to form the action set. In allowing different actions within a single project, the practicality of this situation should be evaluated by the KDOT personnel based on their past experience and judgments.

4. Evaluate the cost constraint for a given action set

The total cost of the action set under consideration for the project should not exceed the upperbound on the cost identified in Step 2. If this constraint is not satisfied, the particular action set is considered to be infeasible and the next action set is analyzed for feasibility.

5. Evaluate the performance constraints for a given action set

In Step 2, one would have determined the probabilities that a randomly selected part of the project would be in acceptable and unacceptable condition states at each of the next five years if the NOS optimal policy is followed. Now, the site-specific performance of the project under the given action set can be estimated using the prediction models to be developed for the POS. To utilize the NOS performance constraints consistently, the POS prediction models should be capable of estimating probabilities that a given segment in the project would be in different condition states as a function of time and the action taken. The performance constraints then would be evaluated by checking whether for the POS models, the probability of being in acceptable conditions at each year is greater and the probability of being in unacceptable condition at each year is less than the corresponding probabilities estimated from the NOS model. Note that the NOS probabilities to be used in this comparison would have been calculated in Step 2. If these constraints are not met by a particular action set, that set is considered to be infeasible and the analysis moves on to the next set.

6. Rank feasible action sets

All action sets which meet the cost and performance constraints in Steps 4 and 5 are considered to be feasible. In this step, the feasible action sets are ranked using some defined criterion and the most preferred action set is identified. Minimum cost can be one of the criteria that could be used. Another criterion that is more comprehensive is the maximum expected utility (value). In this approach tradeoffs between multiple attributes such as cost, distress types, and estimated user costs are assessed using the collective value judgments of KDOT personnel.

POS Framework for New Design

For a new design, NOS cost and performance constraints would not be available. The performance constraint may be set by policy (e.g. 10 years in acceptable levels of distress for new bituminous pavements). It may be possible to determine the funds to be allocated to a new road from the Construction Priority/Optimization System. The framework for checking whether or not these constraints are met would be similar to that shown in Figure 1. A major difference between the two procedures will be in the form of the prediction models for new construction. One needs to predict the performance on observed condition of a road before it is in place. Consequently, variables such as observed condition or measured deflection would not be available to predict future performance. A preferred approach would be to use mechanistic procedures to predict different distress types. Such procedures generally represent a pavement as a multi-layer system whose structural response to given loads is calculated using elastic or visco-elastic theory. The structural response is then correlated with the occurrence of different distress types.

Task Descriptions

The tasks are divided into two parts: (A) those related to POS development and (B) those related to NOS debugging.

(A) POS Development Tasks

Task 1. Finalize the POS framework

A basic framework for the development of a POS was described in the final report for Phase II of the PMS study. This framework will be finalized after reviewing the following questions with KDOT personnel:

- o How much, and what types of, data are available for the development of performance prediction models?
- o Should multiple attributes be used in evaluating alternative rehabilitation strategies for a given project? If yes, which are these factors and what group of individuals should be involved in assessing the Department's preferences regarding the relative importance of the attributes?
- o Are the necessary data available for the various mechanistic procedures (e.g., dynamic modulus, layer thicknesses, etc.)?

A discussion of these questions will be useful in deciding (i) the type of prediction models to be developed for the POS (empirical, mechanistic, or the combination of the two, with objective and/or subjective data); (ii) the process of assessing preference functions; and (iii) mechanistic procedures for new design which are compatible with available data.

A trip report will be submitted to summarize the discussions in the meetings with KDOT and the decisions made.

Task 2. Develop POS prediction models

Models will be developed to predict (1) the performance of existing pavements under different rehabilitation actions and (2) the performance of new roads to be built under alternative initial designs. Uncertainties in predicting future performance will be explicitly incorporated in these models. Thus, the model would predict not only expected performance, but also probabilities of getting performance different from expected.

The prediction models for existing pavements will be developed based on as built data, performance history, and parameters obtained from mechanistic procedures, if appropriate. A large number of influence variables (e.g., independent variables in a multiple regression equation) can be included initially in the model. Using techniques such as stepwise analysis, a smaller set of influence variables which best explain the variations in pavement performance will be selected.

For new roads to be built, the available data will be the design parameters (material properties, traffic, layer thicknesses, etc.). Depending upon types of design data that would be available, an appropriate combination of mechanistic and empirical procedure will be selected.

The existing test sections for "partial design AC pavements" do not satisfy the requirements of a statistically balanced experimental design. It is recommended, therefore, that the development of prediction models for partial design AC pavements be postponed until new test sections are chosen and adequate data on these sections are accumulated. Many

of the existing test sections for other pavement types will also be replaced. Hence the prediction models developed in this task for the other pavement types should be revised after accumulating data for all test sections over a period such as two years.

Insofar as the state-of-the-knowledge permits, mechanistic-empirical models will be used for the development of POS pavement design procedures. If such models do not exist for specific distress types, empirical models will be used for the development of the design procedures.

Data requirements for the development of predictions models for POS will be identified by the Consultant. Data acquisition and compilation will be the responsibility of the KDOT staff.

Task 3. Establish preference functions, as appropriate

If multiple attributes are to be used for the evaluation of feasible rehabilitation strategies, the relative importance of the attributes needs to be established. Formal procedures of assessing multi-attribute preference functions will be used. A panel of KDOT personnel will be established to make the necessary assessments of acceptable tradeoffs between competing attributes.

It is anticipated that a group meeting will be held to explain to the panel members the purpose of the assessments and the procedure that should be followed. Standard assessment forms then will be distributed and the members will be asked to complete the forms one by one. A statistical analysis of the responses on each form will be made to find whether a reasonable group consensus can be

identified. If the responses are extremely divergent, a second iteration on some of the forms may be necessary.

Based on the group consensus identified for the various assessments, a multi-attribute preference function will be calibrated. The procedure of calibration and the major implications of the preference function will be described in a trip report.

Task 4. Develop a computer program for the implementation of the POS

The overall computer program will consist of the following components or subroutines.

a. Form cost and performance constraints

For an in-service project, these constraints will be formed based on NOS results. The upperbound on the project cost will be the sum of the cost of the optimal NOS action for each segment in the project. The performance constraints will be: (i) the minimum probability that a random part of the project is in acceptable condition at each year during a planning period (such as five years) and (ii) the maximum probability that a random part of the project is in unacceptable condition at each year.

For new construction, the cost constraint probably will come from the construction priority/optimization system. Initially, this constraint may have to be set based on past experience and judgment. The performance constraints will have to be set by policy decisions; for example, the expected time to a rehabilitation action should be more than ten years.

b. Find feasible sets of actions

The cost of a feasible action set for an in-service project should be less than or equal to the upperbound on project cost calculated above. In addition, the performance under the action set, as determined from the POS prediction model, should be equal to or better than the performance constraints formed from the NOS model.

For new construction, the cost of each alternative design will be determined from the design specifications and previous cost records. The performance of a new road after it would be built will be estimated from the appropriate mechanistic model selected in the previous task.

c. For each feasible action set, calculate the total expected value

The probability distribution of each attribute will be determined for the action set using the prediction models. The total expected value of the action set will then be calculated from the calibrated preference function.

d. Rank feasible action sets and conduct sensitivity analyses

The feasible action sets will be ranked in a decreasing order of total expected value. The sensitivity of the ranking will be examined with regard to factors such as: differences of opinions on acceptable tradeoffs between competing attributes and policy requirements for new construction.

Task 5. Test and revise POS, as appropriate

The development of the computer program will be completed at the Consultant's office. The program will be then installed and tested on KDOT's computer facilities. Two alternative facilities will be considered: the PLEXUS P/40 and the IBM mainframe. The preferred alternative will be the PLEXUS P/40 system.

Input data for testing the POS will be provided by KDOT. A total of ten test projects (five in-service and five new construction projects) might be selected. The results of POS runs for these projects will be subjected to a "test of reasonableness;" Is the selection of the preferred action set as expected? Do the results show expected trends? Any problems revealed through the examination of these actions will be identified and appropriate revisions to the computer program will be made.

Task 6. Prepare a final report

The final report will document the development of the POS. The prediction models and the preference functions will be fully described, and the testing results will be discussed. A user manual will also be prepared to describe the input-output characteristics of the computer program.

(B) NOS Debugging Tasks

Task 1. Complete the development of interim prediction models

During the current phase of the NOS study, the assessment of subjective data will be completed for all road categories. However, data for only one road category, (RC₁₅), will have

been analyzed. In the proposed task, data for all the remaining categories will be analyzed to determine the consensus values of all the necessary transition probabilities. KDOT will have the responsibility of providing the data from the assessment forms on computer cards or tape. The format for compiling the data will be specified by the Consultant. After identifying the consensus response for each assessment form, a computer tape of the transition probabilities will be submitted to KDOT. These probabilities will then be checked by KDOT personnel for consistency across different road categories and different actions. Appropriate changes will be made by KDOT in the transition probabilities and a revised data tape will be provided to the Consultant.

Task 2. Run NOS programs for all road categories

In the current phase, NOS programs will be tested for road category 15. In the proposed task, NOS programs will be run for all the remaining road categories. The data on costs of alternative actions, specification of feasible actions and performance standards, and current network conditions should be provided by KDOT. The Consultant will compile the transition probability data and prepare necessary input data files to run NOS. These data files will be transmitted to the University of Kansas (KU) personnel, who will run MPSIII on the University's computer system and prepare a summary report using the report writer program.

Task 3. Evaluate the reasonableness of results

The results of all the NOS runs will be examined with regard to the following questions:

- o Are the optimal actions recommended by NOS for different condition states reasonable within each road category?
- o Are the optimal actions for the same or similar condition states reasonable across different road categories?
- o Is the effect of changing performance standards on budget levels according to expectations?
- o Is the division between the proportions of roads assigned to do nothing, routine maintenance, and rehabilitation reasonable?

If the examination of the above question reveals that some of the results are unreasonable or unexpected, causes of such results will be identified and discussed with KDOT. Examples of such causes are overly optimistic or pessimistic transition probabilities for certain actions, inflexible specification of feasible actions, incorrect cost estimates, and unreasonable performance standards.

Task 4. Revise the NOS software as necessary

Appropriate changes in the NOS software will be made to correct the problems identified in the previous task. Additional NOS runs will be made as necessary to make sure that NOS recommendations are reasonable and according to prior expectations. As in the previous task, input data files will be prepared by the Consultant to make the additional runs. The actual runs will be made by the KU personnel.

Task 5. Develop software to prepare a list of road segments and recommended actions

The NOS runs will identify the optimal action for each condition state. Additional software will be necessary to access the data base system and to identify the condition state of each mile. A list of the condition state, the recommended action, and its cost can then be prepared. This task will be the responsibility of KDOT with the Consultant advising as necessary.

Time Schedule and Cost Estimates

A time schedule for completing the proposed work is shown in Figure 2. Note that the time estimates assume that running of NOS problems on MPSIII by KU personnel will be completed in two to three weeks after the input data files have been provided by the Consultants. Table 1 shows estimates of person-hours for various tasks. A detailed breakdown of costs is included in Table 2.

TABLE 1. ESTIMATES OF PERSON-HOURS

(A) POS Tasks

<u>Personnel</u>	<u>No. of Person-Hours for Given Task</u>						<u>Total</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	
R. Kulkarni	100	100	60	100	100	100	560
F. Finn	50	100	50	-	50	50	300
Project Engineer	-	200	100	100	60	60	520
Senior Staff Engineer	-	90	100	400	100	40	730
Typing and Drafting	20	20	60	20	20	100	240
Total	170	510	370	620	330	350	2350

(B) NOS Tasks

<u>Personnel</u>	<u>No. of Person-Hours for Given Task</u>					<u>Total</u>
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	
R. Kulkarni	30	30	30	30	10	130
F. Finn	-	-	72	-		72
Staff Engineer	100	100	60	100		360
Total	130	130	170	130	10	570

TABLE 2-a. COST BREAKDOWN FOR POS TASKS

(A) Salaries and Wages

<u>Personnel</u>	<u>Hourly Rate</u>	<u>Hours</u>	<u>Estimated Cost</u>
R. Kulkarni	\$26.44	560	\$ 14,806
Project Engineer	22.72	520	11,814
Sr. Staff Engineer	15.60	730	11,388
Typing and Drafting	12.00	240	<u>2,880</u>
		Subtotal	\$ 40,888

(B) Consultant Fees

F. Finn	\$50.00	300	\$ 15,000
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(C) Miscellaneous

Computer Time			\$ 16,850
Telephone and Postage			<u>2,000</u>
		Subtotal	\$ 18,850

(D) Travel

Airfare 6 person-trips @ \$700		\$ 4,200
Subsistence 24 person-days @ \$60/day		1,440
Car rental 12 days @ \$50/day		<u>600</u>
	Subtotal	\$ 6,240

(E) Overhead

180% of Salaries and Wages	\$ 73,598
Total Estimated Cost	\$154,576

(F) Fixed Fee

(10% of Total Estimated Cost)	\$ 15,458
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Total Estimated Cost Plus Fixed Fee	\$170,034
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TABLE 2-b. COST BREAKDOWN FOR NOS TASKS

(A) Salaries and Wages

<u>Personnel</u>	<u>Hourly Rate</u>	<u>Hours</u>	<u>Estimated Cost</u>
R. Kulkarni	\$26.44	130	\$ 3,437
Staff Engineer	14.00	360	<u>5,040</u>
		Subtotal	\$ 8,477

(B) Consultant Fees

F. Finn	\$50.00	72	\$ 3,600
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(C) Miscellaneous

Computer Time			\$ 5,000
Telephone and Postage			<u>300</u>
		Subtotal	\$ 5,300

(D) Overhead

180% of Salaries and Wages		\$15,259
Total Estimated Cost		\$32,636

(F) Fixed Fee

(10% of Total Estimated Cost)		\$ 3,264
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Total Estimated Cost Plus Fixed Fee		\$35,900
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TABLE 2-c SUMMARY OF COSTS

	<u>Estimated Cost</u>	<u>Fixed Fee</u>	<u>Total Cost + Fee</u>
POS Development	\$154,576	\$15,458	\$170,034
NOS Debugging	<u>32,636</u>	<u>3,264</u>	<u>35,900</u>
Total	\$187,212	\$18,722	\$205,934

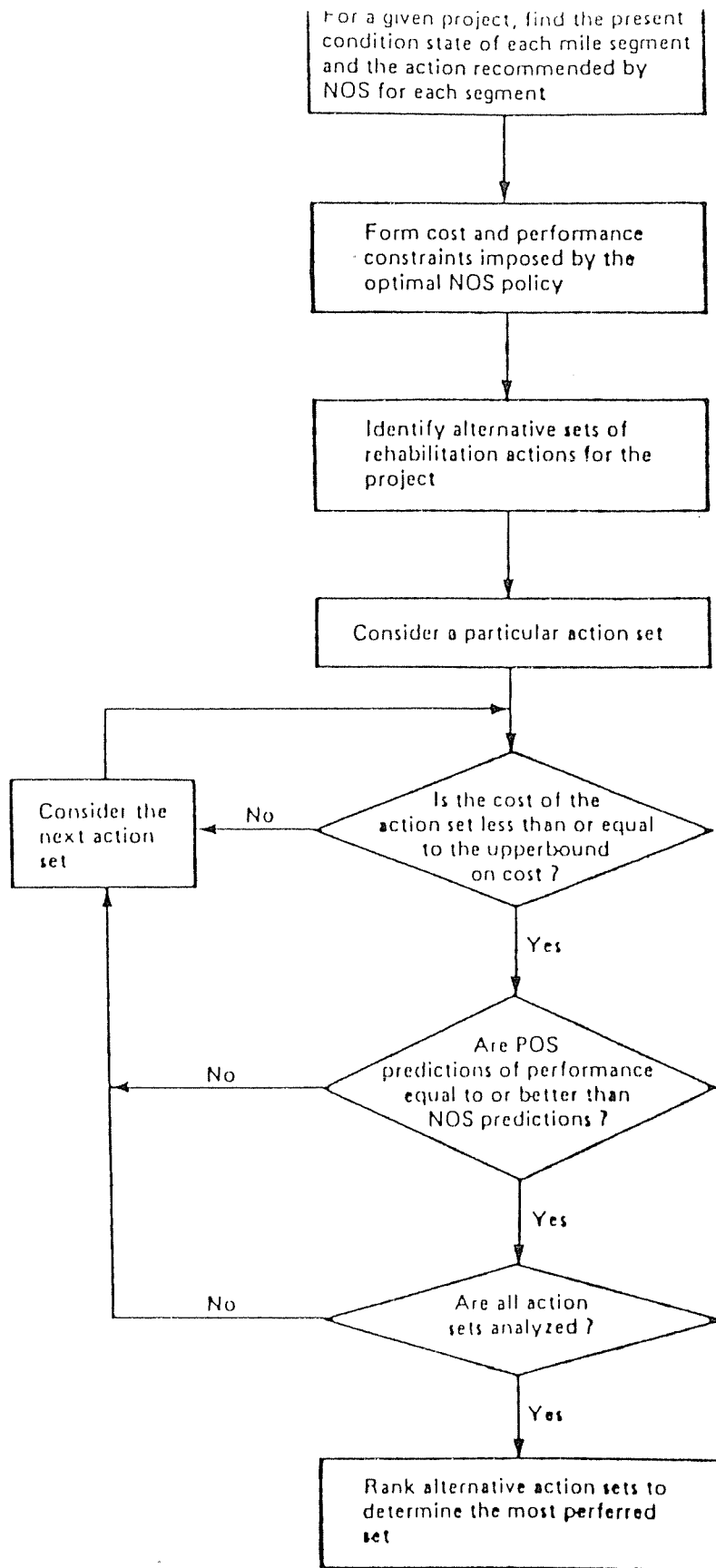


Figure 1 – POS Framework for Rehabilitation of Existing Pavements

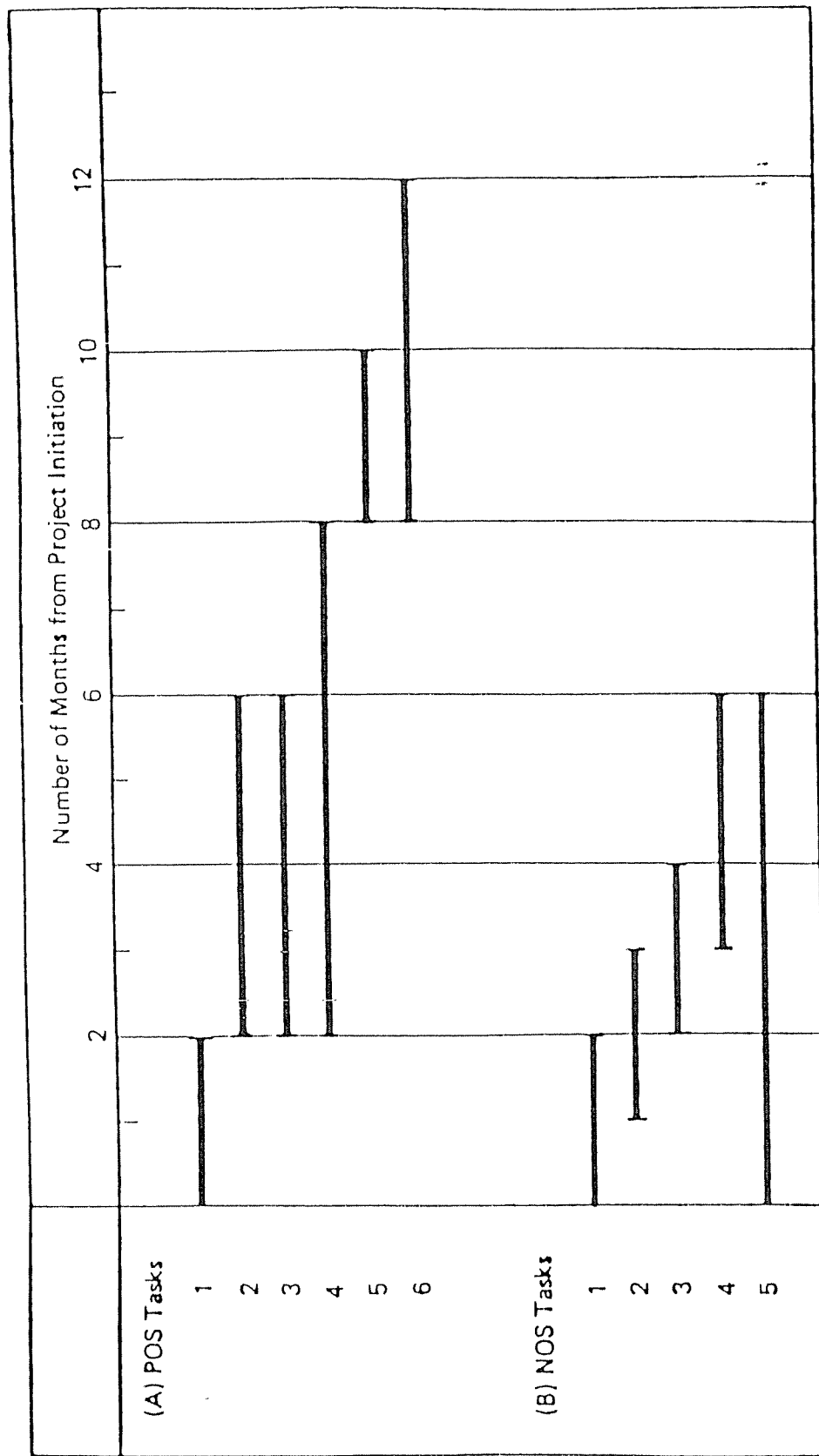


Figure 2 — Time Schedule

AMENDMENT AND SUPPLEMENT TO KANSAS DEPARTMENT OF
TRANSPORTATION CONSULTANT AGREEMENT

This Amendment is made and entered into this 7th day of January 1985, by and between the Secretary of Transportation of the State of Kansas, hereinafter referred to as "Secretary", and Woodward-Clyde Consultants, consulting engineers with principal offices in Walnut Creek, California, hereinafter referred to as "Consultant."

WITNESSETH:

WHEREAS, this Consultant has technical expertise in Pavement Management pursuant to the Agreement for Engineering Services dated November 1, 1983, hereinafter referred to as "Contract", and,

WHEREAS, it is in the best interest of the Secretary to complete development of the Total Pavement Management System at the earliest feasible date, and,

WHEREAS, it would be to the best interest of the Secretary that said Consultant continue to provide engineering services necessary for the development of a Total Pavement Management System as set forth in the Contract, and,

WHEREAS, the Secretary now has the data and resources necessary to allow the Consultant to complete development of the Total Pavement Management System, and,

WHEREAS, the Consultant has submitted a work plan including a budget and a time schedule dated October 4, 1985, hereinafter referred to as "Proposal", which completes development of the Total Pavement Management System for Kansas, and which is acceptable to the Secretary, and,

WHEREAS, it is in the best interests of the parties to have an amended and supplemental agreement to allow for additional time, supplemental work, and increased fees, costs and expense of the Consultant due both to changed conditions in the original Contract and to additional tasks previously reserved for the fourth and fifth contract phases.

NOW THEREFORE, upon mutual promises and consideration herein before made, the parties agree to amend and supplement the Contract attached hereto and incorporated by reference herein, to include the tasks, budget, and time schedule designated and described in the Proposal, also attached hereto and incorporated by reference herein, to provide the following:

1. Upon completion, Tasks 1 - 4, Tasks 6 - 8, and part of Task 15 as described and outlined on pages 1, 3, 4, 5, 6, 7, and 10 of the Proposal are acknowledged by the Secretary as the remaining work originally called for in the Contract.

2. Task 5, Tasks 9 - 14, and the remainder of Task 15 as described and outlined on pages 1, 5, 6, 7, 8, 9, and 10 of the Proposal are added to the Contract and are acknowledged by the Secretary as the remaining work originally designated for Phases IV and V necessary to complete PMS development for Kansas.

3. Task 16 of the Proposal is excluded from this amended and supplemental agreement.

4. Article I, Section 5 of the Contract is amended as follows:

- a) The net fee amount of \$18,722 is increased by \$23,691 to \$42,413.
- b) The upper limit of compensation of \$205,934 is increased by \$260,604 to \$466,538.
- c) The original and amended upper limits specified in 4 (b) do not include \$4847.81 paid in June, 1985 for work beyond the scope of the Contract.
- d) The time for submission of the voucher for final payment for the Project is amended to be after completion and approval by the Secretary of all tasks except task 16 in the Proposal.

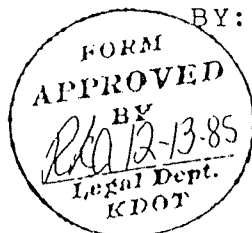
5. Article II, Sections 1 and 2 of the Contract are amended to require a working PMS acceptable to the Secretary at the conclusion of this amended and supplemental agreement, including completion of Tasks 1 - 15 of the Proposal within 13 months from this date.

6. The parties agree that all terms of the original Consultant Agreement and attachments of the original agreement including and not limited to non-discrimination clauses approved by the parties, will have full force and effect and the only modifications in the Contract will be the new completion date, contract amount, and additional tasks set forth.

IN WITNESS WHEREOF, the parties have caused this Amendment and Supplement to Kansas Department of Transportation Consultant Agreement to be signed by their duly authorized officers on the day and year first above written.

Lawrence B. Kulbarten
WOODWARD-CLYDE CONSULTANTS

W. H. Wright
JOHN B. KEMP
Secretary of Transportation
of the State of Kansas
BY: W. H. WRIGHT
State Transportation Engineer



04 October 1985
85P2057

Attachment "C"

Mr. G. Norman Clark, P.E.
Kansas Department of Transportation
2300 Van Buren Street
Topeka, KS 66611

Dear Norman:

Pursuant to our telephone conversation, I am writing to provide cost estimates to complete the PMS development for Kansas. The original plan for PMS development included five phases which were described in my letter of 17 June 1982 addressed to Mr. Glen Koontz. Since an adequate amount of pavement condition survey data are now available, NOS and POS prediction models based on objective data can be developed. Thus, the remainder of Phase III work and the work in Phases IV and V can now be combined into a single phase to be completed by December 1986. The enclosed report defines and briefly describes the tasks necessary to complete the PMS development and provides task-by-task estimates of the level of effort and costs.

It should be noted that the scope of current Phase III work included the development of POS prediction models based on objective data, an activity that was originally included in Phase IV. Also, a complete optimization capability is provided in the POS developed in the Phase III work; the original Phase III plan included only a priority ranking procedure and not an optimization method. Consequently, the cost for completing Phase III will be greater than our original estimate. However, the estimated costs for completing Phases IV and V are now lower than the original estimates because part of the Phase IV work will be completed in Phase III. In fact, the total costs of completing the remaining Phase III work and the work in Phases IV and V are about the same (except for inflation adjustment) as our original estimates for completing Phases IV and V. I hope that you will understand that in a multi-year research study, some shifting of the level of effort and cost from one part of the study to another is quite likely to happen.

Please call me if you have any questions or need additional information.

Sincerely,



Ram B. Kulkarni
Project Manager

RBK:RK-0055p*

encl.

Consulting Engineers, Geologists
and Environmental Scientists

Office or Other Principal Cities



WORK PLAN TO COMPLETE THE PMS DEVELOPMENT FOR THE STATE OF KANSAS

This work plan describes the tasks necessary to complete the PMS development for Kansas and provides task-by-task estimates of level of effort and costs. A time schedule to complete the various tasks is also included.

Task Descriptions

The following tasks will be necessary to complete the development of a comprehensive Pavement Management System (PMS) for the Kansas Department of Transportation (KDOT):

- Task 1. Calibrate a mechanistic reflection cracking model.
- Task 2. Calibrate a mechanistic transverse cracking model.
- Task 3. Develop a mechanistic roughness model.
- Task 4. Develop empirical models for block cracking, faulting, and joint distress.
- Task 5. Develop mechanistic/empirical models for Partial Design Bituminous (PDBII) pavements.
- Task 6. Complete the development of Project Optimization System (POS) software.
- Task 7. Install and test POS software on KDOT's computer facilities.
- Task 8. Develop procedures for updating and recalibrating POS prediction models as additional data are generated.

- Task 9. Establish procedures for modifying Network Optimization System (NOS) prediction models using objective data.
- Task 10. Develop NOS prediction models based on objective data.
- Task 11. Test and revise NOS with the latest prediction models.
- Task 12. Test and revise POS with the latest prediction models.
- Task 13. Assist in using the complete system (NOS and POS) to develop pavement preservation programs and budgets.
- Task 14. Write a report describing procedures to update NOS prediction models.
- Task 15. Prepare a final report on the development of POS.
- Task 16. (Optional) Develop a methodology to select optimal pavement preservation policies for all road categories simultaneously, subject to budgetary restraints.

Note that Tasks 1 through 4, Tasks 6 through 8, and part of Task 15 belong to the remaining Phase III work. The remaining tasks (except for Task 16) belong to the original Phase IV or V work. Task 16 is optional and was not included in the original work plan. The need for this task has arisen because KDOT finds that the NOS runs have to be made in a fixed budget mode. An efficient method for finding optional policies under an overall network budget constraint, therefore, would be very desirable.

A brief description of each of the sixteen tasks is provided below.

Task 1. Calibrate a Mechanistic Reflection Cracking Model

Reflection cracking on composite pavements will result in transverse cracking. The basic objective of this task will be to calibrate the existing reflection cracking analysis and overlay design program (KANRC) based on the performance of overlay sections in Kansas. The key technical activities in this task will be as follows:

1. Obtain meteorological data on minimum daily temperatures during a year.
2. Obtain or estimate in situ measurements of horizontal slab movements over a two- or three-day temperature cycle.
3. Obtain measurements of per cent reflection cracking from field "calibration" sections.
4. Predict horizontal movements for field calibration sections which have already been overlayed.
5. Tabulate reflection crack history for all field calibration sections.
6. Obtain or assign structural and material properties for each field calibration section.
7. Use the KANRC program to generate the critical asphalt concrete overlay tensile strains necessary to develop and calibrate a cumulative damage model.
8. Incorporate the revised damage model into the KANRC program.

Task 2. Calibrate a Mechanistic Transverse Cracking Model

The objective of this task will be to develop a cumulative damage model (similar to that described in Task 1) which can be used to predict low-temperature and hence transverse cracking on Full Depth Bituminous (FDBIT) pavements. The specific technical activities under this task are similar to those for Task 1. In this case, the COLD program will be used to develop the associated low-temperature stresses for each of the FDBIT overlay sections for which empirical performance data are available. Work by M.Y. Shahin on low-temperature cumulative damage models for Texas will be combined with COLD as a starting point for the Kansas model.

Task 3. Develop a Mechanistic Roughness Model

The objective of this task will be to develop a roughness-based cumulative damage model based on (1) the model being developed for Arizona DOT and (2) the performance of experimental test sections in Kansas. The nature of the Arizona model makes it possible to consider seasonal variation of roadbed soil support in developing the new model. Below is a list of the key subtasks associated with the proposed approach:

- (1) Identify the "best" sections (up to ten) for use in developing the model. (Selection criteria are based on the availability and extent of structural and performance data.)
- (2) Identify the pavement and roadbed soil material properties for each season of the year.
- (3) Tabulate the cumulative traffic versus roughness (Maysmeter) history for each of the ten sections selected in (2) above.

- (4) Predict the critical pavement response (asphalt concrete tensile strain, surface deflection, or roadbed soil vertical stress) for each season of each section.
- (5) Use the Arizona model to determine the "effective" pavement response for each section.
- (6) Develop a regression model which correlates roughness history with cumulative traffic and the "effective" pavement response.
- (7) Document model development.

Task 4. Develop Empirical Models for Block Cracking, Faulting, and Joint Distress

Multiple regression analysis will be used to estimate the probability of occurrence of a given distress level as a function of variables such as material properties, type of rehabilitation action, environmental conditions, and traffic.

Task 5. Develop Mechanistic/Empirical Models for Partial Design Bituminous (PDBIT) Pavements

Models will be developed to predict fatigue cracking and transverse cracking on PDBIT pavements. The Probability Distress Models for Asphalt Pavements (PDMAP) program will be used as a basis for the development of a fatigue cracking model. The model developed in Task 1 will be used for the prediction of transverse cracking. Both of these models will be calibrated with observed performance histories of sample PDBIT pavements. Procedures for material testing will be identified in order to develop the inputs for structural analysis. It is anticipated that much of the testing data developed for full design bituminous pavements

can be used for PDBIT pavements as well and that significant additional testing will not be required.

Task 6. Complete the Development of POS Software

POS will consist of two separate but interrelated computer programs:

1. Program SCREEN - This program compares alternative sets of actions for each project under consideration and screens out the sets of actions which do not meet NOS performance standards. The benefit is computed for each of the remaining sets of actions.
2. Program SELECT - This program selects the optimal group of project-action combinations that maximizes the total benefits subject to specified budgetary constraints.

Both of these programs have been partially developed. The primary remaining work is to incorporate the performance prediction models once such models are finalized in the previous tasks. The program SCREEN needs access to large NOS data files and hence has been designed in PL/I to be executed on KDOT's main-frame computer. The program SELECT has been written in FORTRAN and can be executed on the PLEXUS P/40 available at the KDOT Materials Research Center.

The program SELECT is essentially complete; only certain report formats need to be written. The program SCREEN can be computed only after the performance prediction models are finalized.

Task 7. Install and Test POS Software on KDOT's Computer Facilities

The program SCREEN will be installed on KDOT's main-frame computer, and the program SELECT will be installed on the PLEXUS P/40 system.

After implementing SCREEN, the output files will be transferred to the PLEXUS system and will serve as input to the program SELECT. The program SELECT will evaluate alternative project-action combinations and find the optimal combination, i.e., the combination that will maximize benefits subject to an overall budget constraint. Both the programs -- SCREEN and SELECT -- will be tested with real data, any bugs or potential problems will be identified, and appropriate revisions to the programs will be made.

Task 8. Develop Procedures for Updating and Recalibrating POS Prediction Models as Additional Data Are Generated

Additional experimental and field data on pavement conditions and material properties will be generated by KDOT staff through future pavement condition surveys and laboratory testing. Procedures will be developed in this task to utilize the future data to update and recalibrate POS prediction models for different distress types. The approach will be to modify the input parameters of the models by using the total data base of information available to date. Recalibration of the models will be possible through correlation/regression analysis of the cumulative pavement condition data.

Task 9. Establish Procedures for Modifying NOS Prediction Models Using Objective Data

The current transition probabilities in NOS prediction models were developed based on subjective judgments of KDOT engineers. By July, 1986, five years of pavement condition data will be available and can be used to derive the transition probabilities. Procedures will be established to calculate transition probabilities based on both the initial subjective estimates and estimates that could be obtained directly from the objective (field) data. The approach will be to count

the number of transitions made from one condition state in a given road category to other condition states in one year. By calculating the proportion of the total number of transitions from condition state i to condition state j following action a_k , the transition probabilities $p_{ij}(a_k)$ can be estimated from the analysis of the field data. To combine the subjective and objective estimates of transition probabilities, appropriate weights will be assigned to the two sets of estimates, and weighted average transition probabilities will be calculated. The weight assigned to the objective estimates may be the number of transitions on which the estimates are based. The weight assigned to the subjective estimates will have to be assessed by considering the equivalent number of transitions that the consensus subjective estimate may be assumed to represent. For example, the equivalent number of transitions may be assumed to be equal to the cumulative number of years of experience exhibited by the panel of maintenance engineers who provided the subjective estimates of transition probabilities.

Task 10. Develop NOS Prediction Models Based on Objective Data

The procedures developed in Task 9 will be implemented to obtain transition probabilities that utilize both objective and subjective data with appropriate relative weights assigned to the sources of data. It is anticipated that KDOT staff will be responsible for processing the pavement condition survey data to produce the data summaries required for the estimation of transition probabilities. The Consultant will identify the necessary data summaries and advise KDOT staff regarding data processing activities to produce these summaries. The Consultant will write a computer program to obtain updated transition probabilities. This program will be designed to run on the PLEXUS system. The KDOT staff will execute this program to generate updated transition probabilities, which will be used in subsequent NOS runs.

Task 11. Test and Revise NOS with the Latest Prediction Models

The Consultant will assist the KDOT staff as necessary to run steady-state and five-year NOS problems for all road categories with the latest NOS prediction models. The Consultant will review the summary results from these runs and will assist KDOT in assessing the reasonableness of the results. Projections of expected budgets and performance will be examined to check whether they are realistic and consistent with previous experience. If any problems are found in the process of interpreting and evaluating results, the causes for these problems will be identified, and appropriate revisions to the NOS software or inputs will be made.

Task 12. Test and Revise POS with the Latest Prediction Models

The Consultant will assist KDOT in executing the POS software using the latest NOS and POS prediction models. Assistance will also be provided in interpreting POS results and selecting project-specific rehabilitation actions. The results will be examined for reasonableness and consistency with previous experience. Any deficiencies identified in the POS software or inputs will be corrected.

Task 13. Assist in Using the Complete System (NOS and POS) to Develop Pavement Preservation Programs and Budgets

The complete system will be checked to make sure that the individual systems (NOS and POS) and the interface between the two systems are working properly. The Consultant will assist KDOT in the development of multi-year pavement preservation programs and budgets using the results of NOS and POS.

Task 14. Write a Report Describing Procedures to Update NOS Prediction Models

A report will be prepared to describe procedures for updating NOS prediction models as pavement condition data are generated each year. These procedures will be illustrated with the data used in Task 10 to revise the initial NOS prediction models.

Task 15. Prepare a Final Report on the Development of POS

The final report will describe POS framework and document the development of the mechanistic/empirical prediction models and of the POS software. A user manual will also be prepared to describe the input-output characteristics of the various POS computer programs.

Task 16. (Optional) Develop a Methodology to Select Optimal Pavement Preservation Policies for all Road Categories Simultaneously, Subject to Budgetary Constraints

The current NOS optimization model seeks maintenance policies that minimize total expected costs subject to achieving prescribed performance standards. This approach permits analyzing each road category separately. The total minimum cost for the entire network would then be the sum of the minimum costs for the individual road categories. However, if this model is to be used in a fixed-budget mode (i.e., maximize performance standards subject to a fixed budget constraint), an iterative procedure is necessary. If the same performance standards applied to all road categories, then systematic changes (upward or downward) in these standards can be made until a match with the available network budget is obtained. However, if different performance standards are selected for various road categories to reflect different traffic levels and functional classes, then there could be several alternative

combinations of performance standards, all of which could meet a fixed budget constraint. It may be a very time-consuming and tedious process involving several iterations to find the combination that meets the fixed budget constraint and provides a reasonable distribution of performance among the various road categories. Basically, the current NOS optimization model was designed to work in the cost minimization mode and is not well suited in a fixed-budget mode. My letter of February 17, 1984, addressed to Mr. G. Norman Clark describes an approach to operate NOS either in a fixed-performance mode or a fixed-budget mode at the discretion of the user. This optional task will develop and implement such an approach. This will provide the ability to analyze all road categories simultaneously to directly determine the maximum performance standards that could be achieved for a fixed budget for the entire network.

ESTIMATES OF LEVEL OF EFFORT AND BUDGET

Table 1 shows the number of person-hours of various individuals assigned to each of the tasks. Table 2 provides budget estimates for Tasks 1 through 15. The estimated budget for the optional Task 16 is shown in Table 3.

TIME SCHEDULE

Figure 1 shows a time schedule for initiating and completing each of the sixteen tasks.

Table 1. ESTIMATES OF PERSON-HOURS BY TASKS

Personnel	Number of Person-Hours for Given Task														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R. Kulkarni	16	16	16	16	100	60	40	24	60	120	120	130	32	40	80
R. Finn	160	160	280	40	40	--	--	--	--	--	--	--	--	--	--
E. Alvitl/Staff Engr.	40	40	40	80	160	160	80	24	60	160	120	120	40	40	120
Drafting	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Typing	10	10	10	10	10	10	10	10	10	10	10	10	10	80	80
Total															

Table 2. BUDGET ESTIMATES FOR TASKS 1 THROUGH 15

Personnel	Hourly Rate	Hours	Cost
<u>(A) SALARIES AND WAGES</u>			
R. Kulkarni	\$37.24	870	\$ 32,399
E. Alviti/Staff Engr.	19.04	1284	24,447
Drafting	16.00	160	2,560
Typing	14.00	330	<u>4,620</u>
		Subtotal	\$ 64,026
<u>(B) CONSULTANT FEES</u>			
F. Finn	\$62.50	680	\$ 42,500
<u>(C) MISCELLANEOUS</u>			
Computer Time			\$ 3,500
Telephone and Postage			2,000
Report Production			<u>2,000</u>
		Subtotal	\$ 7,500
<u>(D) TRAVEL</u>			
Airfare 8 person-trips @ \$700/trip			\$ 5,600
Subsistence 24 person-days @ \$60/day			1,440
Car rental 12 days @ \$50/day			<u>600</u>
		Subtotal	\$ 7,640
<u>(E) OVERHEAD</u>			
180% of Salaries and Wages			\$115,247
TOTAL ESTIMATED COST			\$236,913

Table 2. BUDGET ESTIMATES FOR TASKS 1 THROUGH 15 (concluded)

	Hourly Rate	Hours	Cost
(F) <u>FIXED FEE</u>			--
10% of Total Estimated Cost			\$ 23,691
TOTAL ESTIMATED COST PLUS FIXED FEE			\$260,604

Table 3. BUDGET ESTIMATES FOR OPTIONAL TASK 16

Personnel	Hourly Rate	Hours	Cost
<u>(A) SALARIES AND WAGES</u>			
R. Kulkarni	\$37.24	135	\$ 5,027
E. Alviti	19.04	580	11,043
System Analyst	22.00	590	<u>12,980</u>
		Subtotal	\$29,050
<u>(B) MISCELLANEOUS</u>			
Computer Time			\$ 5,000
Telephone and Postage			1,000
Report Production			<u>1,000</u>
		Subtotal	\$ 7,000
<u>(C) TRAVEL</u>			
Airfare 2 person-trips @ \$700/trip			\$ 1,400
Subsidence 6 person-days @ \$60/day			360
Car rental 3 days @ \$50/day			<u>150</u>
		Subtotal	\$ 1,910
<u>(D) OVERHEAD</u>			
180% of Salaries and Wages			\$52,290
		TOTAL ESTIMATED COST	\$90,250
<u>(E) FIXED FEE</u>			
10% of Total Estimated Cost			\$9,025
		TOTAL ESTIMATED COST PLUS FIXED FEE	\$99,275

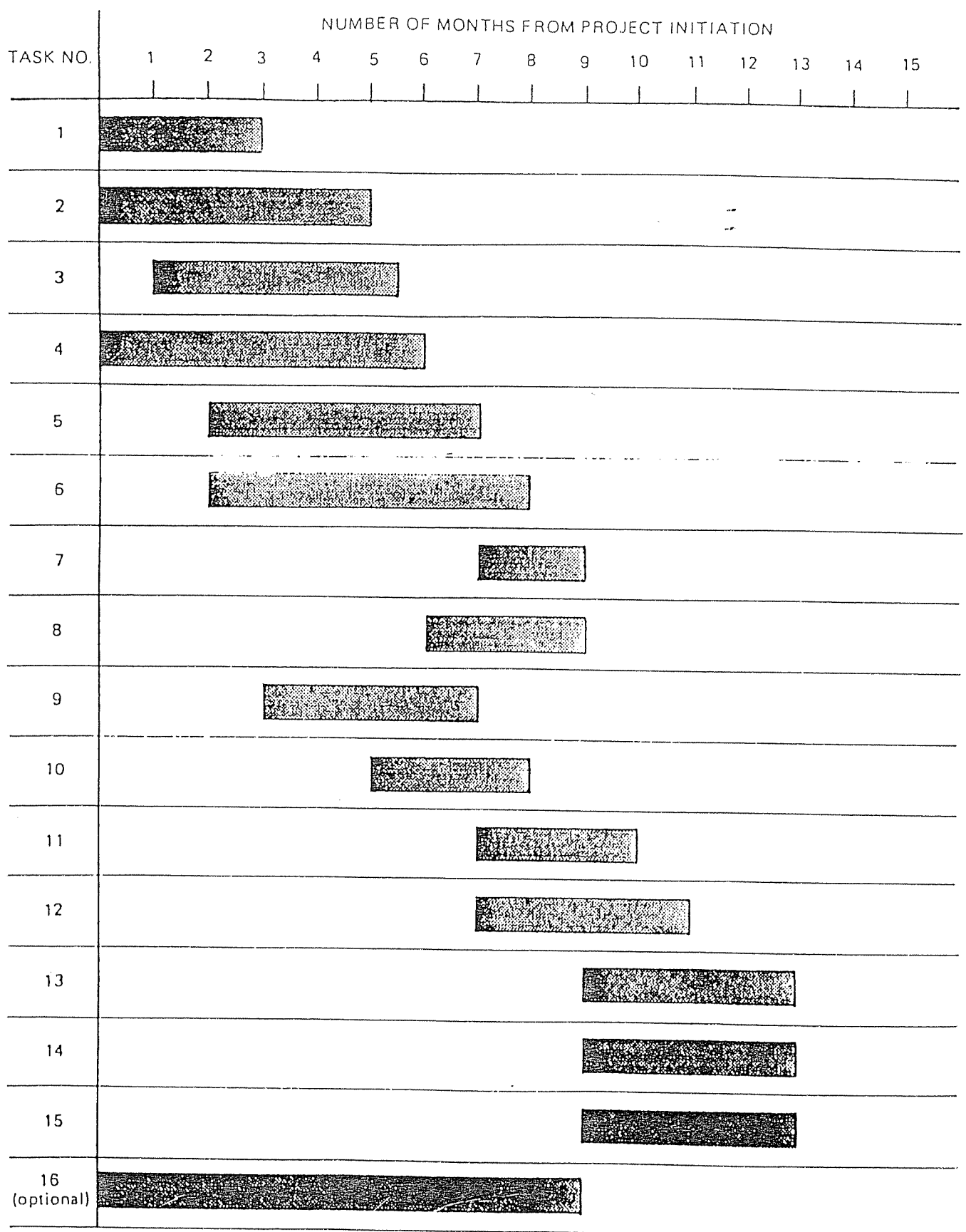


Figure 1. TIME SCHEDULE

January 10, 1990

MEMORANDUM OF UNDERSTANDING
BETWEEN
THE ALASKA DEPARTMENT OF TRANSPORTATION
AND PUBLIC FACILITIES
AND
THE ARIZONA DEPARTMENT OF TRANSPORTATION
AND
THE KANSAS DEPARTMENT OF TRANSPORTATION

I BACKGROUND

The Kansas Department of Transportation (KDOT) has implemented a Network Optimization System (NOS) which maximizes benefits from the expenditure of rehabilitation funds. This system is one of three modules in KDOT's Pavement Management System.

The model used in the current NOS directly addresses the question *"what are the minimum budget requirements necessary to maintain prescribed performance standards?"* The reverse question, *"what maximum performance standards can be maintained from a fixed budget?"*, can only be answered through an iterative approach. In a constrained funding environment, the reverse question must always be answered requiring solutions of multiple linear programming problems. This approach places heavy demands on computer resources. Also, the resulting solution is questionable since several combinations of performance standards can be chosen which will allow the "solution"/"optimal rehabilitation strategy" to meet the fixed budget.

Because of a need to more directly address the "fixed budget" solution, KDOT has entered into a consulting engineering agreement to enhance the methodology used in NOS. The enhancement will provide:

- Two options for the Objective Function -- Minimize Costs or Maximize Benefits.
- Optimal Allocation of the Total Network Budget Among Individual Road Categories, and identification of total benefit for individual road categories.

II SCOPE of MEMORANDUM OF AGREEMENT

The methodology currently used in KDOT's NOS is identical to that used in software operated by the Alaska and Arizona Departments of Transportation. Further, the enhanced algorithm to be developed for KDOT is directly applicable to these agencies.

Because of mutual needs, the Alaska Department of Transportation and Public Facilities, and the Arizona Department of Transportation agree to participate with KDOT in the development effort and will receive full benefits from the enhanced system at

approximately one third of the development cost. At the conclusion of the development effort, each state will receive:

- The enhanced software package written in PL/1
- The user manual
- Assistance in system installation from KDOT's consultant

The cost estimate for the NOS enhancement is as follows:

- Consultant fees for development, testing, installation and manuals (contract upper limit) ----- \$146,247
- Data Transmission Costs ----- \$ 19,753
- Data Processing Costs ----- \$ 83,000
- Estimated Total Cost ----- \$249,000
- Cost to each state (1/3 of Total) ----- \$ 83,000

To facilitate the development effort, each of the three states shall:

- Convert to latest NOS-3 Version (Presently running in Alaska under VM/CMS).⁽¹⁾
- Convert VM/CMS command files to MVS/WILBUR or MVS/ROSCOE command files if the state plans to use MVS/WILBUR or MVS/ROSCOE.
- Use MPS -III (Preferably with WHIZARD), or if MPSX is used, convert MPS-III/VM command files to MPSX/MVS command files.
- Write their own Report Writer Programs (Beyond those provided by NOS-3).
- Provide a "Road Segment Information File" to run program NETWRT.
- Provide a SXSIN file compatible with NOS-3.
- Provide transition probabilities in fixed format (not E format).
- Provide "benefit coefficients" for different distress states.⁽²⁾
- Provide "relative importance factors" for individual road categories.⁽²⁾

(1) To be provided by KDOT's consultant.

(2) Procedure to be provided by KDOT's consultant.

III IMPLEMENTATION

Implementation of this joint development effort will include the following activities by the Departments of Transportation in Alaska, Arizona, and Kansas:

A. Alaska

- Provide computer resources necessary for development. These resources are estimated at 100 CPU hours and are valued at approximately \$83,000.
- Oversee installation and operation of a data communications link between Juneau, Alaska, and Oakland, California. (Costs for installation and operation are to be billed to KDOT)

B. Arizona

- Participate in the development costs billed to KDOT in an amount not to exceed \$73,124.
- Participate in the data transmission costs billed to KDOT in an amount not to exceed \$9,876.

C. Kansas

- Administer consultant contract
- Keep Alaska and Arizona informed on project development progress.
- Pay all contract development charges from the consultant up to the contract upper limit of \$146,247; and all data transmission charges up to \$19,753 for the joint development effort.
- Bill the Arizona DOT for one half of all development, and one half of all data transmission charges up to Arizona's agreed levels of participation.


IV DEVELOPMENT SCHEDULE

- | | |
|---------------------------------|----------------------|
| • Model Development | 01/15/90 to 05/15/90 |
| • Software Development | 04/15/90 to 10/15/90 |
| • Software Testing and Revision | 08/15/90 to 12/15/90 |
| • User Manual | 11/15/90 to 01/15/91 |

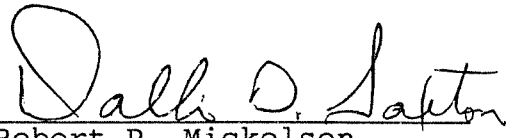
V WITNESS

The undersigned witness that this Memorandum of Understanding is mutually acceptable, and is in effect for the duration of the described development effort beginning on the day and year written above.

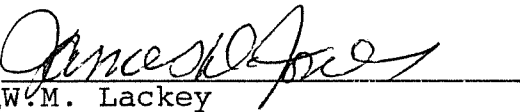
STATE OF ALASKA
Department of Transportation
and Public Facilities

By: 
Jeffery C. Ottesen
Director of Operations and
Engineering Standards

STATE OF ARIZONA
Department of Transportation

By: 
for Robert P. Mickelson
Deputy State Engineer

STATE OF KANSAS
Department of Transportation

By: 
W.M. Lackey
State Transportation Engineer